Comprehensive environmental management systems for stormwater runoff

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Mission

- We are concerned with promoting multidisciplinary approaches to sustainable environmental management systems
- And accomplishing this calling through the integration of hydrologic, ecological, economic, and legal perspectives.

Research Focus

- One way that we articulate this mission is through the examination of storm water runoff regimes in urban ecosystems, and how these might be better managed.

Importance of impervious surface

- Impervious surface is one of the primary agents of hydrologic change in urbanizing watersheds
- Its impacts on hydrologic cycles and terrestrial ecological regimes are multifold
- The mechanisms through which these impacts are manifested are not well understood, hampering effective management of these impacts.

Major projects

- We have identified two specific research areas:
- In-situ watershed assessment of the alteration of hydrologic cycle in response to urbanization (Coshocton OH); and
- Determine costs and benefits of distributed, participatory approaches to managing storm water runoff at the watershed scale (Shepherd Creek OH).

Indicators and their utility – a looming question

- For each of these projects we test for the utility of indicators or models as to how well they mark conditions or change in the environment
- We then evaluate how ones uses indicators to evaluate whether a prescription or treatment was successful in improving endpoint values from their baseline condition

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Coshocton Urbanization Project

A unique research setting

- Established by USDA-ARS, late 1930's
- Nearly 30 sub-watersheds,draining from 1 to 5000 acres
- Charged to study the effects of climate and different types of agricultural management on site hydrology
- Up to 60 years of hydrologic data from selected watersheds
- Part of a nationwide network of watershed stations; different climate zones, soils

Research rationale

- USEPA and USDA-NRCS are interested in knowing the specific effects of urbanization on watershed hydrology and water quality
- The purpose of this research is to quantify these impacts under *controlled and realistic experimental conditions*

Anticipated benefits

- Come to understand runoff formation and routing processes at practical scales of management
- Provide support for improved modeling practice (e.g., SWMM, SWAT, WMS, AGNPS, TR55)
- Develop innovative best-management practices (BMPs) for controlling runoff through in-situ testing and evaluation

Laboratory component

Laboratory component: objectives and approach

- Develop laboratory rainfall simulation methods sensitive to different sizes and arrangements of impervious surface
- Evaluate the hydrologic, erosional, and water quality impacts of these various impervious surface configurations
- This data will be used to inform correspondent field work

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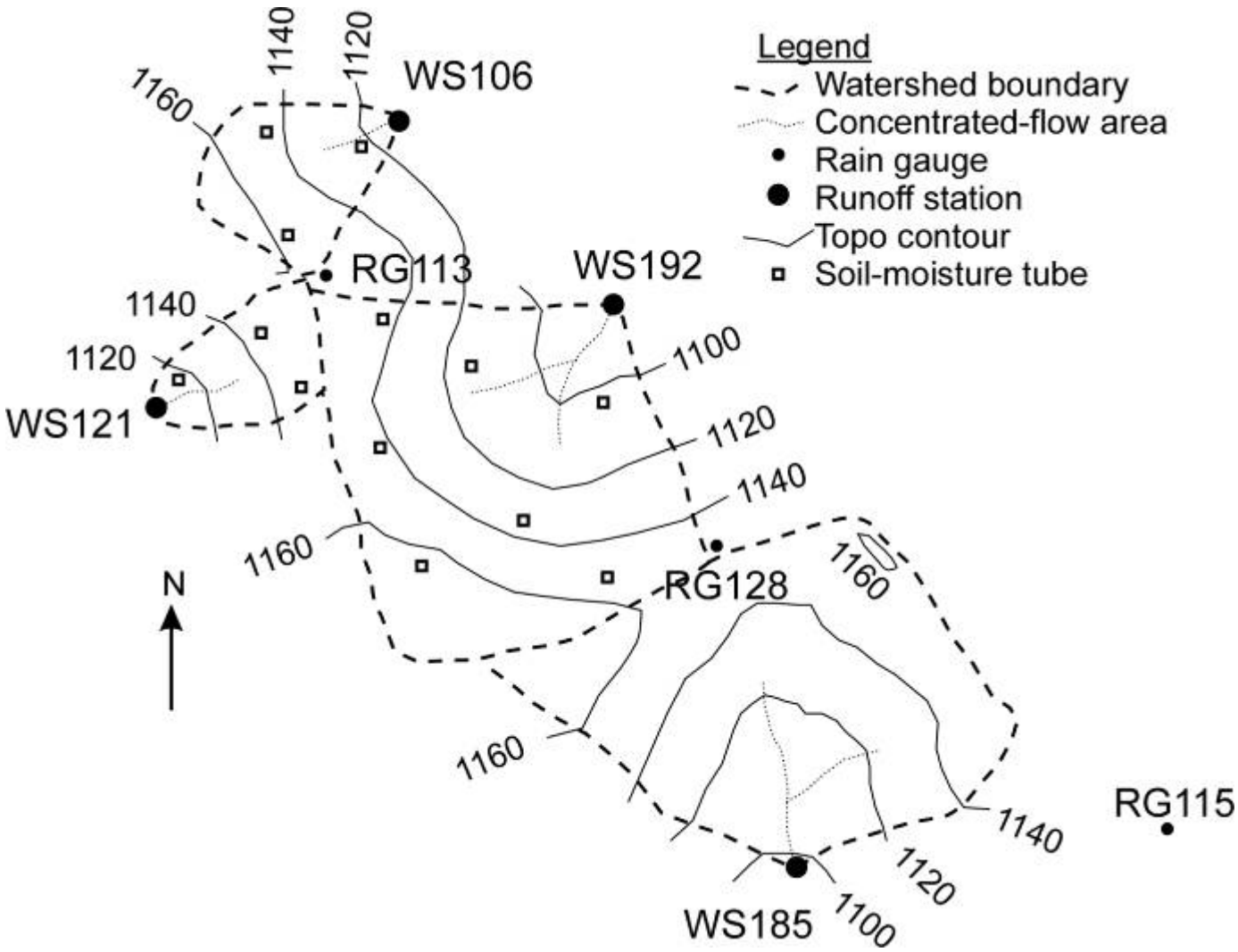
Field Component



Field component: Objectives

- Expand laboratory concepts to field scale
- Smaller watersheds committed exclusively to BMP testing and evaluation
- Larger watersheds are used to monitor impacts of stepwise urbanization

Field component: Approach

- Stepwise increase in percent impervious surface (0 to 40 percent, in 5 percent steps); then implement BMPs at 40 percent level
- We will also simulate pervious surfaces in the form of either seeded or sod turf crops
- Impervious surface will be implemented as pitched-guttered roofs (larger watersheds), roads (smaller watersheds)

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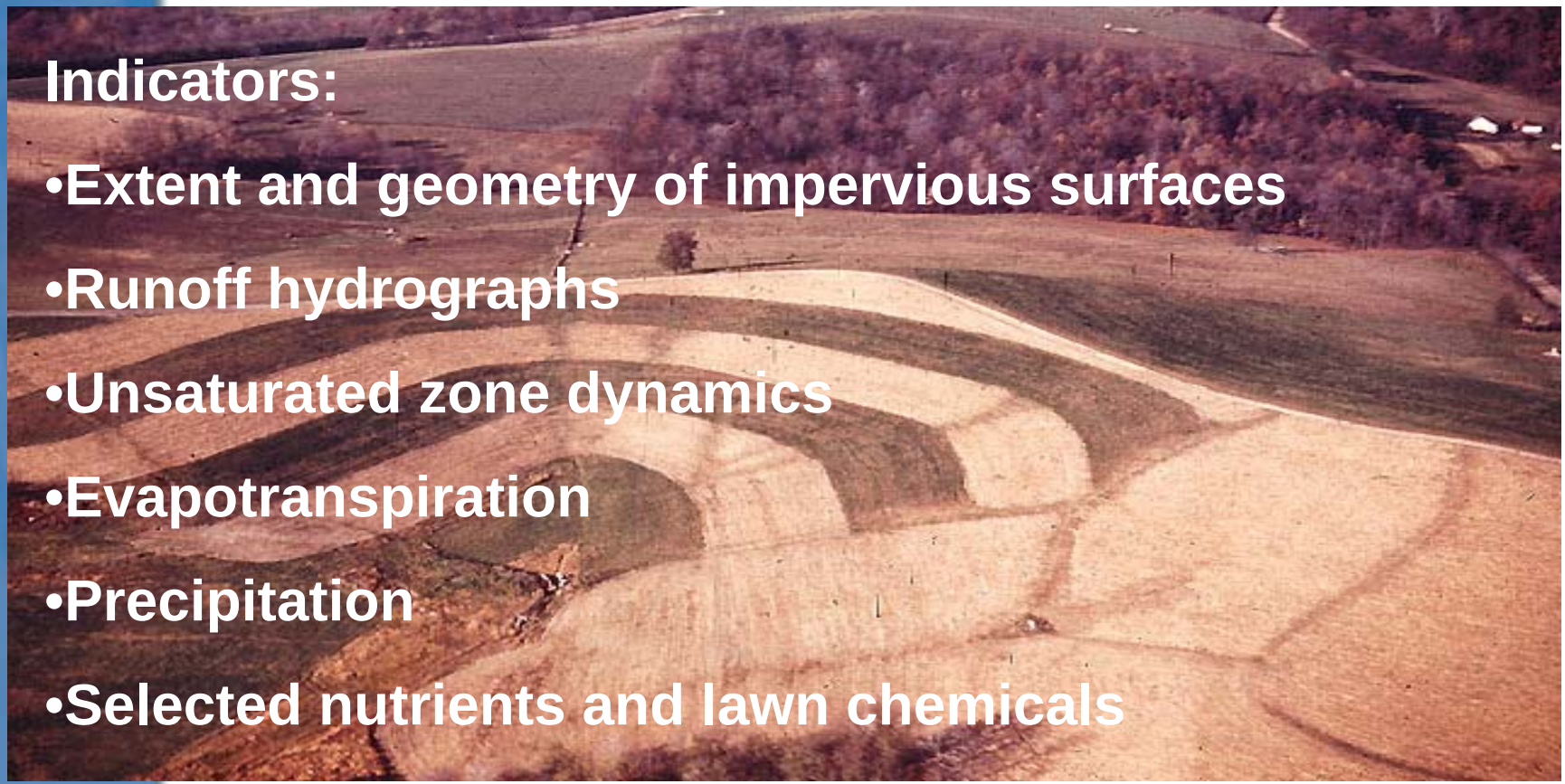
Track watershed responses to development



Indicators:

- **Extent and geometry of impervious surfaces**
- **Runoff hydrographs**
- **Unsaturated zone dynamics**
- **Evapotranspiration**
- **Precipitation**
- **Selected nutrients and lawn chemicals**

Project Timeline

- Stepwise implementation of impervious surfaces in larger watersheds planned for Fall 2004
- Implement roads in smaller watersheds to generate elevated runoff, test BMPs
- We depend on natural precipitation regimes to accumulate data – variable time frame

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The Shepherd Creek Pilot Watershed - Multidisciplinary management of stormwater runoff

Centralized versus decentralized stormwater management

Decentralization of Best Management Practices (BMPs)

- Attempt to more closely mimic pre-development hydrologic regimes
- Residential: rain barrels, rain gardens
- Commercial/Industrial: detention/retention ponds, porous pavement

Shepherd Creek pilot project goals

- Develop legal, socially-acceptable method for management of stormwater quantity
- To reduce or eliminate existing sources of runoff, we aim to couple patterns in economic behaviors with hydrologic and ecological endpoints to eventually implement BMPs
- Then we will link costs with any observed hydrologic and ecological benefit

Shepherd Creek project: research questions

- Will a decentralized management strategy lead to significant hydrologic and ecological improvements in the watershed?
- Will an economically-based market mechanism provide the appropriate incentives to install sufficient BMPs throughout a watershed?

Tradable allowances for stormwater control?

- Challenges
  - water quantity not regulated
  - stormwater fees not tightly tied to excess runoff
- Potential solution
  - auction approach
    - relies on strategic trading behavior, but in more controlled environment

Economics: general

- Effective BMP adoption will incorporate:
  - hydrologic considerations
  - economic incentives
  - stakeholder participation.
- Employ tradable allowance system to determine stakeholder willingness to adopt BMPs for use in designing a successful market mechanism

Earlier modeling effort indicated benefits

- Earlier modeling work estimated total cost of BMPs implemented through tradable credit system
- This work suggested that this cost would be significantly less per unit volume than other, more infrastructure-intensive abatement schemes
- May offer a unique tool to municipalities to improve stormwater management

Economics: preliminary case study

- Design an auction to purchase stormwater BMPs from private landowners in Shepherd Creek
  - Develop a computerized bidding game that simulates the auction and test with student (local university) test population
  - Run the computerized bidding game with sub-groups of landowners in SC to calibrate
  - Use results to estimate the price of stormwater BMPs in this watershed and refine the BMP auction approach

Development of pilot project

- Carry out the auction with homeowners in Shepherd Creek & install BMPs
- To determine the ecological effectiveness of this economic policy instrument, long-term monitoring needs to be done

Shepherd Creek pilot project: monitoring effort

- Before-After, Control-Impact (BACI) experimental design
- ***Impact*** in this study is the implementation of BMPs in headwaters, and on the basis of economic incentives
- Ecological and hydrologic data are collected periodically before and after impact

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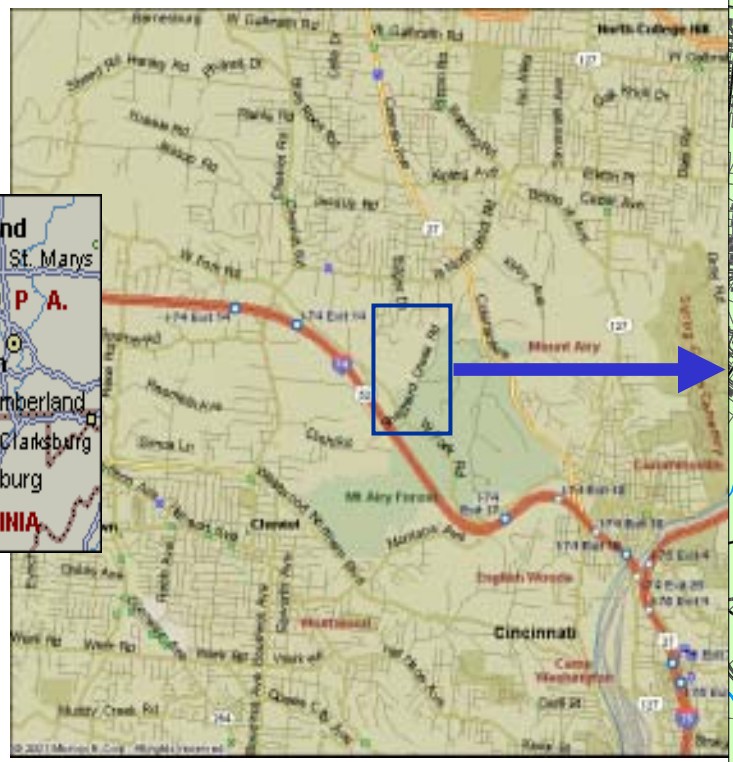
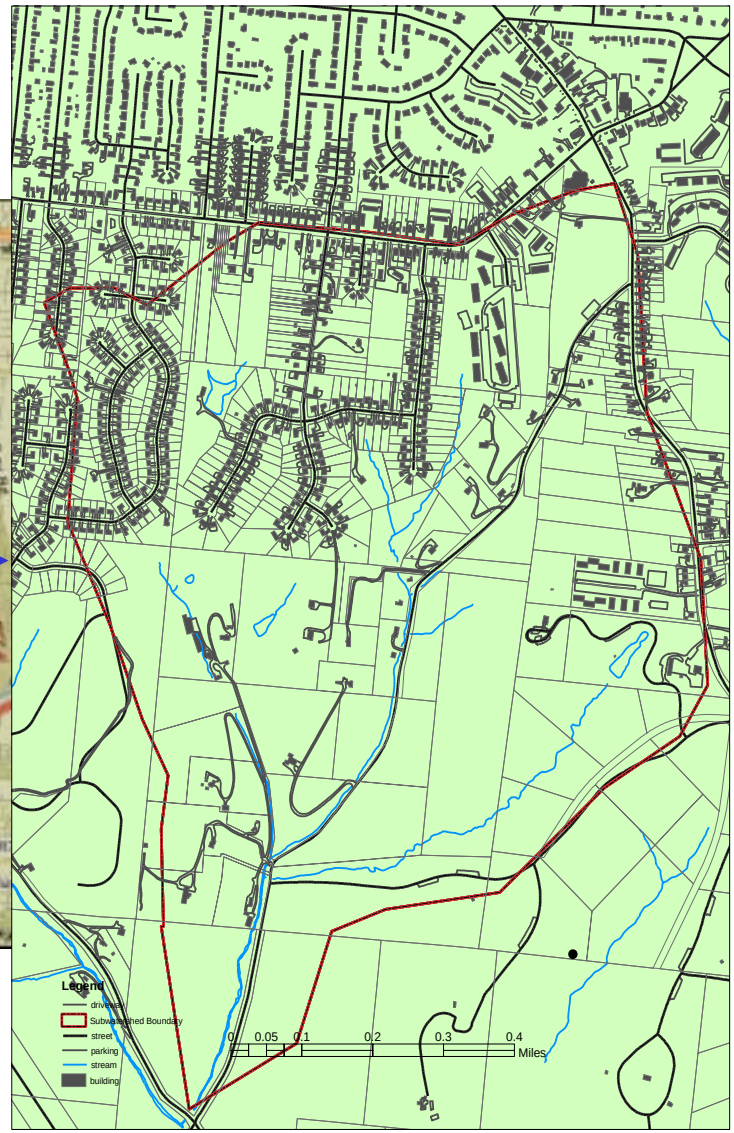
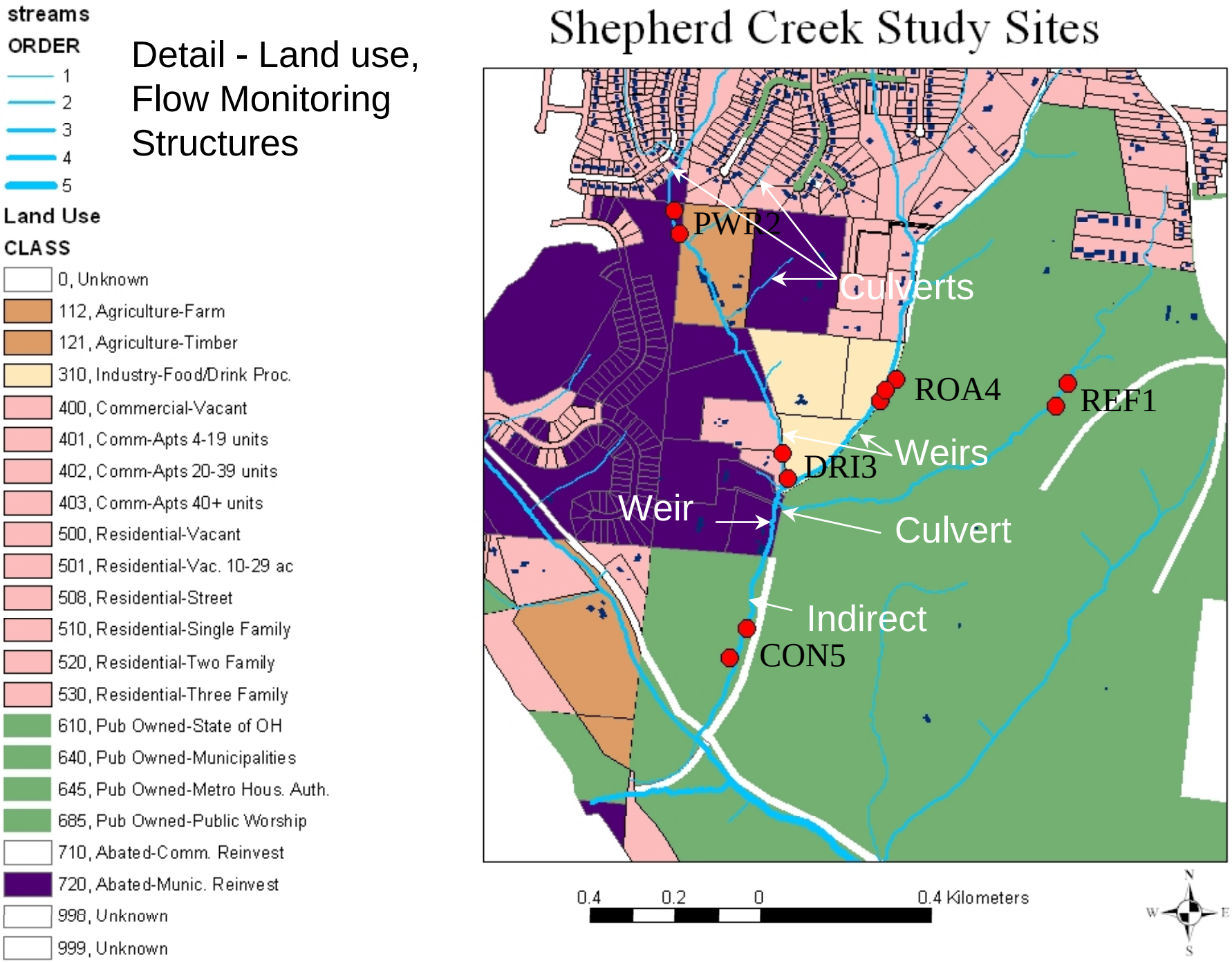
Shepherd Creek: geography





Shepherd Creek Study Sites

Detail - Land use, Flow Monitoring Structures



Example 1: Reference, forested site

- Located within Mt. Airy forest, a city park
- This site represents a healthy headwater stream, for this area
- Alluvial bed, woody debris, reasonable meander

Example 2: Residential, treatment site

- Headwaters were filled, culverted to channel flows into this reach
- Moderate meander giving way to channelization and lateral migration is considerable
- Adjacent to CSO

Hydrologic, ecological monitoring data

- Hydrology-Sedimentology
  - Discharge
  - Precipitation
  - Evapotranspiration
  - Stream morphology
  - Sediment dynamics
  - Soil Hydrology
  - Detailed soil survey
- Ecology
  - Algae
  - Aquatic invertebrates
  - In-stream habitat
  - Riparian habitat
- Water Quality
  - Basic microbiology
  - pH, DO, °C
  - Turbidity
  - N,P, Anions

Project Timeline

- We expect BMP implementation in either 2006 or 2007, with at least 2 years post-installation monitoring
- Economic effectiveness of auction format will be evaluated in 2007
- Hydrologic ecological effectiveness evaluated in 2009